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Aggregation of an Orchard and a Vegetable Soil Under Different Cultural Treatments

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AGGREGATION OF AN ORCHARD AND A VEGETABLE SOIL UNDER DIFFERENT CULTURAL TREATMENTS

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INTRODUCTION

Orchardists and gardeners are probably as much concerned with the structure, or physical nature, of the soil as they are with its chemical composition. Regardless of what the chemical nature may be or what the fertilizer treatment may consist of, soil structure may greatly limit the productive capacity of the soil. The physical nature and chemical composition of soil are interrelated in many ways. For example, soil organic matter benefits the soil both in its relation to structure and eventually in relation to its chemical or fertilizer values (particularly nitrogen).

The state of aggregation of a soil does not measure its complete and final structural composition, but a measure of the degree of aggregation does present one of the major factors concerned.

Under certain conditions, mineral soil and organic matter particles become united with each other to form crumbs of different sizes. Those which are most concerned in the structure of the soil are stable in water. These aggregates may be considered as units of the soil structure which remain as such during seasonal and moisture changes within the soil complex.

The ideal aggregate structure is evidently not yet known, and it would probably vary considerably with different soil types. A desirable state of aggregation allows plant roots to develop easily through the soil, principally by permitting air and water to move through it at an optimum rate. Soil aggregates aid in the resistance of soil to erosion, and, to some extent, to cultivation. They aid in resisting the shattering effect of rain and wind on soil. A well-aggregated soil will allow the maximum rate of intake of soil moisture and also be of benefit in conserving it.

The purpose of this bulletin is to present results of an aggregate analysis of two general soil types which had been under different cultural treatments for a long period of time. An effort was also made in these studies to determine some of the factors underlying the formation of soil aggregates in Wooster silt loam.

LITERATURE REVIEW

No attempt is made here to review all the literature concerned with soil aggregation, but some of it closely related to the problems discussed is mentioned briefly.

Evidently little investigation has been made of the relative size and distribution of soil aggregates under sod, mulch, and cultivation treatments over long periods. These treatments are found principally in orchards, to a lesser extent in forests. Browning and Sudds (4), reporting their work on some orchard soils in West Virginia, showed that orchards in sod contained a much higher percentage of the larger-sized aggregates than those under cultivation. In Pennsylvania (9) it was found that cultivation with cover crops in an orchard caused a reduction in organic matter, granule stability, and probably permeability of the surface soil. A bluegrass sod gave the highest organic content and the greatest structural stability and permeability in the surface 3-inch layer. Elson and Lutz (6) found that a desirable state of aggregation, such as that obtained by the use of crop rotation, reduced runoff and erosion. The condition of the organic matter had more effect than did the total amount present in bringing about aggregation.

Metzger and Hide (12) found that the more aggregated portions of the soil contained more organic carbon. Browning (3), Baver (1), and others have also indicated that soil organic matter seemed to be closely related to the degree of aggregation. Rost and Rowles (16) concluded that clay and organic matter were the factors limiting soil aggregation. Base-exchange capacity was found to be closely related to aggregation. They found that cultivation led to a marked reduction in aggregation of forest soils and to little change in that of prairie soils. Aggregation of cultivated soils was restored in the laboratory by adding small amounts of humus extracted from black prairie soil. Martin and Waksman (10 and 11), Peele and Beale (14), and Retzer and Russell (15), however, are among those who have shown that perhaps the organic matter content is related more indirectly to aggregation. They have pointed out the effect of soil microorganisms and their secretions on aggregate formation. Several workers (11, 12, and others) have pointed out the evident benefit of lime to aggregate formation.

Woodruff (17) found that plots receiving manure for 50 years or rotations including the use of green manures had a higher state of aggregation than untreated plots cropped continuously. Bertramson and Rhoades (2), working in Nebraska, found no difference in percentage of aggregates greater than 0.5 mm. in diameter for manured and unmanured plots. Uncultivated soil had 32.8 per cent of the aggregates greater than 0.5 mm., whereas manured and unmanured, both cultivated, soils had slightly more than 4 per cent of the aggregates greater than 0.5 mm. in the surface soil.

METHODS AND PROCEDURE

METHODS OF ANALYSIS

The aggregate analysis presented here was made according to the Yoder (18) method (fig. 1). The samples were taken during July and August of 1942 by use of the California soil tube, partly dried, and then crushed to pass through a 5-mm. screen. More satisfactory results were obtained if the soil was passed through this screen before it had become completely air-dry. Several screenings were made of each sample in order to avoid pulverization as much as possible. Fifty-gram samples of air-dried soil were used in each determination. At least five replications were run, and the average was calculated and presented in the results published here. Samples were allowed to slake for about 30 minutes in water on the top screen of the nest before the machine was started. The aggregation machine was run at 24 oscillations per minute for 35 minutes.

The weight of the mechanical separates in each size classification obtained by the graded nest of screens used was determined by the following method: Each sample of each size class obtained was treated, first, with hydrogen peroxide and, then, with chromic acid. The samples were then washed thoroughly, and the dispersion was completed by use of sodium oxalate, in general according to the procedure outlined by Olmstead et al. (13). Only the weight of the mineral or mechanical separates which fell into each of the size classes determined was obtained for each of the original size classes.

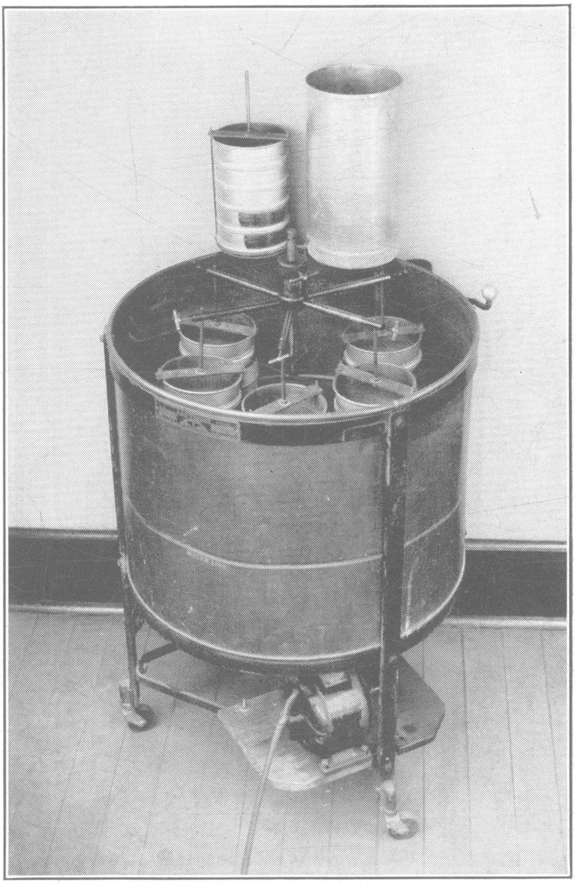

Fig. 1.—Apparatus employed in the determination of water-stable soil aggregates according to the Yoder method of analysis. Soil is placed in the top screen, and the nest of screens moves up and down in the container filled with water.

No complete mechanical analysis for each size class was made. A partial mechanical analysis was made of each soil studied according to the procedure outlined. Mechanical particles greater than 0.25 mm. in diameter and those less than 0.05 mm. were determined in percentage of total weight of mineral soil.

ORCHARDS STUDIED

The orchards used in these tests are located at the Ohio Agricultural Experiment Station, Wooster, Ohio, on Wooster silt loam soil. This is a very good orchard soil, and average yields have been high under all soil treatments described here. Soil aggregate formation is relatively low, however, on this soil type.

Orchard C.—Orchard C is an apple orchard that was planted in 1915. Half the trees have been cultivated continuously with cover crops of soybeans for the summer and rye for the winter and early spring. There has been some variation, however, in recent years, when oats, Sudan grass, and corn have been used. The other half of the orchard was planted in bluegrass sod, and the mulch system was begun at once. Enough mulch was applied to keep down the growth of grasses and weeds beneath the branches. Aside from these two systems of culture, orchard practices have been the same in both blocks.

Growth and yields of trees in both blocks have been above average for the region, and the mulched trees have been showing some superiority in recent years.

Tree roots are well distributed in the Wooster silt loam soil of this orchard to a depth of 6 to 7 feet. Samples were taken in as nearly comparable positions as possible under each treatment. Mulch and cultivation samples were taken from under the drip of the branches, and sod samples from positions adjacent to the mulched area. In each treatment, 10 borings were made, each to a depth of approximately 18 inches. The soil was separated by observation into A and B horizons on removal from the soil tube.

Orchard A.—This orchard is in the same type of soil (Wooster silt loam) as Orchard C. It was planted in 1893 and for 6 years was cultivated. Then it was seeded down, and mulch was applied around the trees. Sod and mulch have been maintained continuously for 44 years. As the diameter of the heads of the trees increased in size, the width of the mulch was extended to as far as the outermost branches. Wheat straw has been used most extensively for mulch, although oat straw, alfalfa, timothy, soybean straw, sweet clover, grass clippings, and corn stover have all been used to some extent. The exact amount used has not been recorded, but it has been ample to prevent any growth of grasses beneath the trees. Usually it has been 3 to 5 inches in depth over the mulched area.

In 1927, the treatment of trees in one block of Orchard A was changed from sod-mulch to cultivation. Since then, this block has been cultivated and sown to cover crops of soybeans and rye.

The system of sampling described for Orchard C was employed here. The soil was not quite so uniform, however, as in Orchard C, and the results were not so striking, a condition found true of other soil determinations made in the two orchards.

Peach orchard.—The peach orchard used in these studies was also on Wooster silt loam and was very near the other orchards described. The trees were set out in the spring of 1935, planted 20 feet apart, eight trees per plot, and each plot was duplicated. The treatments were started in the fall of 1935 and in the spring of 1936. The six treatments given are:

> Plot 1. Manure, 16 tons per acre per year, plus cover crops of soybeans during the summer and rye during the fall, winter, and early spring. The manure was applied in the spring before the soybeans were planted.

Plot 2. Bluegrass sod with wheat straw mulch around the trees. Samples were taken beneath the mulch.

Plot 3. Chopped corn stover, approximately 14 tons per acre per year, plus cover crops of soybeans during the summer and rye during the fall, winter, and early spring. The stover was applied in the spring before the soybeans were planted.

Plot 4. Cover crops of soybeans during the summer, and rye during the fall, winter, and early spring were used.

Plot 5. Cover crops of Sudan grass during the summer and rye during the fall, winter, and early spring. The rye in this plot was disked down about 2 weeks later than that on the other plots each year.

Plot 6. Bluegrass sod with the soil worked up around the trees to a radius of about 3 feet. Soil samples were taken from beneath the trees but under the sod.

Aside from the plot treatments outlined, the culture of the peach orchard has been the same for all plots.

Trees in this orchard have been vigorous and productive except in the plots in bluegrass sod (plot 6) and sod-mulch (plot 2). When the trees were small, results from these plots were not so satisfactory. Here the limiting factor has been available nitrogen. The most productive plot and the one in which the trees show the greatest annual growth has been that with chopped corn stover (plot 3).

Erosion has not been great in any of the plots, but evidently none has taken place in the sod or sod-mulch plots.

Soil samples were obtained from this orchard in the same way as described for Orchard C. Since there was considerable variation in the soil in the peach orchard, special care was taken in an effort to secure comparable samples. Only plots near each other and on as nearly as possible the same type of soil were used. Nevertheless, it was felt that the samples obtained in this orchard were not as comparable as those obtained in Orchard C.

SHORT-TIME SOIL TREATMENTS

In the early spring of 1942, 12 round metal frames 23 inches in diameter and 18 inches in depth were prepared and placed in round holes of slightly greater diameter and depth. Wooster silt loam soil was placed in these containers, in which the treatments were as follows:

1. Surface soil mulched with 4 inches of wheat straw which had been exposed to weathering for about 9 months
2. Surface soil mulched with 4 inches of unweathered wheat straw; 1 pound of sucrose applied on the straw
3. Surface soil mulched with 4 inches of unweathered wheat straw
4. Surface soil mulched with 4 inches of alfalfa
5. Surface soil mulched with 3 inches of ground cork such as that used for insulation purposes
6. Surface soil mulched with 3 inches of ground cork plus 1 pound of sucrose
7. Surface soil mixed with 7 pounds of hydrated lime

8. Soil mixture composed of 50 per cent surface soil and 50 per cent subsoil (from B horizon)
9. Surface soil plus 1 pound of sucrose placed on surface of the soil
10. Surface soil and 2 pounds of sucrose placed on surface of soil
11. Surface soil mulched with 4 inches of rock wool
12. Surface soil mulched with 4 inches of rock wool; 1 pound of sucrose placed on surface of mulch

Care was taken to secure uniform soil mixtures. The surface soil had been used for a garden and for strawberries and had been well fertilized. It was fairly fertile and contained about 2.5 per cent organic matter. Treatments were started April 27, 1942. Samples for aggregate analysis were taken June 8, July 8, and August 10 to a depth of 6 inches.

VEGETABLE SOILS AT MARIETTA

A detailed soil survey map of these experimental plots, a description of the treatments, and other information on the Marietta vegetable plots are given in a recent bulletin by Bushnell (5).

Plots which had received different amounts of manure in their treatment over a period of 28 years were selected for soil aggregate study. A brief outline of the treatments in the plots studied is given in table 1. Since there were differential treatments on two distinct types of soil, certain plots were selected from both Chenango loam and Chenango fine sandy loam soils.

TABLE 1.—Fertilizer and organic matter treatments of vegetable plots used in aggregation studies

	Chenango loam soil		Chenango fine sandy loam soil
Plot No	Treatment (per acre)	Plot No	Treatment (per acre)
2	1915-22—16 tons manure 400 pounds superphosphate 1923-30—16 tons manure 800 pounds superphosphate 1931-42—8 tons manure 1,000 pounds 0-8-0	28	1915-30—16 tons manure 400 pounds superphosphate 1 ton lime 1931-42—16 tons manure 1,000 pounds 8-6-4
3	1915-30—16 tons manure 1931-42—8 tons manure 1,000 pounds 8 8-0	29	1915-30—no treatment 1931-42—1,000 pounds 8-12-8
4	1915-30—No treatment 1931-42—1,000 pounds 8-12-8	33	1915-30—1 ton lime 1931-42—no treatment
5	1915-22—16 tons manure 1923-30—20 tons manure 1931-42—16 tons manure 1,000 pounds 8-8-0		
22	1915-30—No treatment 1931-42—1,000 pounds 8-12-8		

Samples were obtained during July 1942. They were taken with a California soil tube to a depth of approximately 16 inches and divided by observation into the A and B horizons. The A horizon included the surface soil to a depth of about 7 inches, and the B horizon was approximately between the 9- and 15-inch depth. Samples were secured at 10 positions in each plot. The soil in the plots was fairly uniform on the surface, but occasional variations in texture were noted below the first 10 inches.

These Chenango soils at Marietta are terrace or second-bottom soils of the Muskingum River. The surface is brown, the subsoil yellowish-brown. Drainage is good.

Crops of tomatoes, cabbage, cucumber, and sweet corn are grown in each plot in a 4-year rotation. In addition to the treatments described in table 1, cover crops of soybeans are grown on plots 2, 3, and 5 after the cabbage crop, and with the tomatoes and sweet corn following the last cultivation. Rye was sown in all plots in the fall and plowed under in the late fall or winter The manure was added during the late winter or early spring of each year.

RESULTS

RESULTS FROM ORCHARDS AT WOOSTER

Orchard C.—The results of the aggregation analysis in Orchard C follow closely the organic matter content of the soil as determined previously (7). In a 50-gm. sample of air-dry soil, there were few aggregates above 0.5 mm. in diameter in the cultivation treatment in the A horizon (table 2 and fig. 2). In the A horizon under mulch, however, more than one-half the weight of soil used was in aggregates over 0.5 mm. in diameter. The sod treatment was intermediate between the cultivation and the mulch in this horizon but more closely resembled the mulch in the high degree of aggregation (table 2 and fig. 2). There was little difference due to treatment in the B horizon, but there was an indication of the same trend as in the A horizon. It was not at all striking, however, and the mechanical analysis of the soil would probably account for greater differences than the treatment.

Very little of the increased aggregation found in the A horizon under the mulch and sod treatments could be accounted for by difference in mechanical analysis. The mechanical soil particles were fairly similar in their distribution (table 2). Organic matter, total porosity, and infiltration rates, however, all showed differences which seem directly related to those obtained by these aggregation studies. Previous studies (7) showed that the surface soil under mulch and sod was much higher in organic matter, total porosity, and in rate of water absorption than the cultivated soil in this orchard.

Orchard A.—The distribution of aggregates of different sizes in Orchard A showed the same general trend as that described for Orchard C. The most significant difference was that there were more of the larger-sized aggregates in the surface soil under the sod. In horizon A under the 44-year-old mulch, about 50 per cent of the soil was made up of aggregates over 0.25 mm. in diameter (fig. 3). Only slightly less than this percentage of the soil under the sod was above 0.25 mm. in diameter. A very small proportion of the soil under the cultivated treatment was made up of aggregates larger than 0.25 mm., and this difference is the most significant one in the surface soil, or A horizon.

TABLE 2.—Aggregation and mechanical analysis of A and B horizons after 28 years under different treatments in Orchard C (Wooster silt loam)

Treatment	Horizon		Size classes in mm. Average oven-dry weight in gm. per 50 gm. of air-dry soil							Pulverization modulus*	Mineral particles	
			>2	2-1	1-0.5	0.5-0.25	0.25-0.105	0.105-0.05	<0.05		>0.25 Pct.	<0.05 Pct.
Mulch	A	Total separates	9.19	10.56	8.75	4.16	3.77	2.68	9.74	...	2.4	87.2
		Mechanical separates	.15	.19	.16	.11	.24	.68	...	...	...	...
		True aggregates	9.04	10.37	8.59	4.05	3.53	2.00	...	1.62	...	...
Mulch	B	Total separates	.98	3.51	6.02	6.34	7.67	12.21	11.41	...	4.5	83.1
		Mechanical separates	.38	.31	.26	.23	.60	1.23	...	...	...	...
		True aggregates	.60	3.20	5.76	6.11	7.07	10.98	...	.86	...	...
Sod	A	Total separates	6.13	7.92	8.20	5.70	3.81	5.64	11.18	...	2.1	86.8
		Mechanical separates	.15	.16	.17	.12	.19	1.15	...	...	...	...
		True aggregates	5.98	7.76	8.03	5.58	3.62	4.49	...	1.35	...	...
Sod	B	Total separates	.68	3.93	6.17	6.36	9.51	11.24	11.05	...	4.3	81.0
		Mechanical separates	.39	.31	.30	.26	.86	1.37	...	...	...	...
		True aggregates	.29	3.62	5.87	6.10	8.65	9.87	...	.88	...	...
Cultivation	A	Total separates	1.11	2.66	4.46	7.63	9.87	11.04	12.04	...	2.8	86.0
		Mechanical separates	.39	.35	.42	.53	.78	1.00	...	...	...	...
		True aggregates	.72	2.31	4.04	7.10	9.09	10.04	...	.82	...	...
Cultivation	B	Total separates	.31	3.55	5.33	7.26	7.77	11.92	13.13	...	4.1	84.2
		Mechanical separates	.23	.35	.17	.19	.50	1.47	...	...	...	...
		True aggregates	.08	3.20	5.16	7.07	7.27	10.45	...	.83	...	...

*A single-valued figure used for describing the degree of soil pulverization. It is the sum of the cumulative weights of aggregates of greater diameter than the successive openings in the graded nest of screens, beginning with the largest, divided by 100.

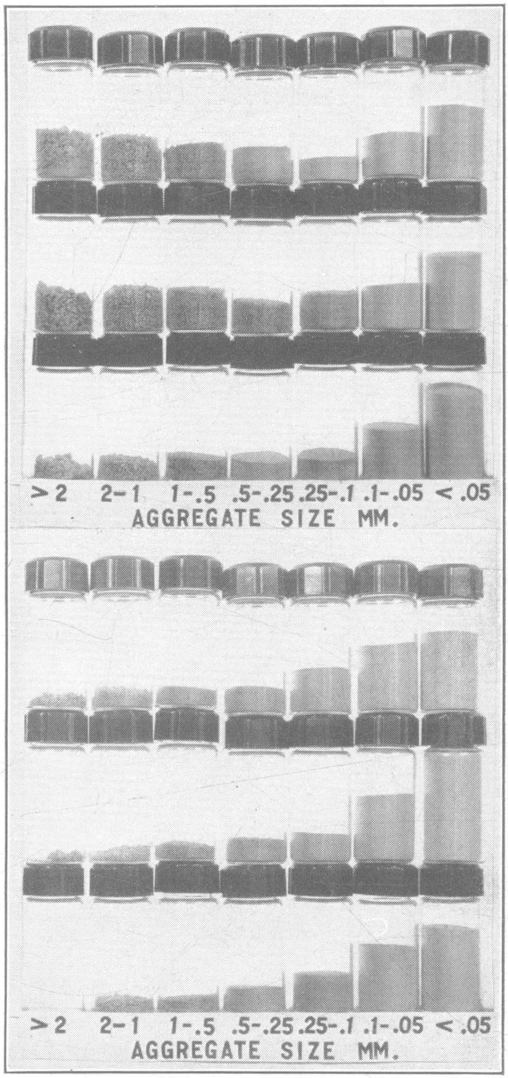

Fig. 2.—Aggregation of Wooster silt loam soil after 28 years under different orchard treatments. Orchard C

Upper, A horizon
Lower, B horizon

The degree of aggregation in the B horizon in this orchard showed the same general trend as found in the surface soil, but the differences were not so striking (table 3 and fig. 3).

TABLE 3.—Aggregation and mechanical analysis of A and B horizons after 44 years under different treatments in Orchard A (Wooster silt loam)

Treatment	Horizon		Size classes in mm.									
			Average oven-dry weight in gm. per 50 gm. of air-dry soil							Pulverization modulus	Mineral particles	
			>2	2-1	1-0.5	0.5-0.25	0.25-0.105	0.105-0.05	<0.05		>0.25	<0.05
											Pct.	*Pct.*
Mulch	A	Total separates..........	7.17	7.67	5.84	5.34	5.01	7.89	10.55	....	2.2	87.0
		Mechanical separates...	.30	.28	.28	.23	.43	.86	....	....	....	....
		True aggregates........	6.87	6.39	5.56	5.11	4.58	7.03	....	1.27	....	....
Mulch	B	Total separates..........	2.56	3.62	4.33	6.20	7.44	12.81	12.17	....	3.1	80.3
		Mechanical separates...	.66	.34	.27	.22	.85	2.59	....	....	....	....
		True aggregates.......	1.90	3.28	4.06	5.98	6.59	10.22	....	.85	....	....
Sod	A	Total separates........	5.23	6.28	6.35	5.05	5.99	8.88	10.78	....	3.2	86.2
		Mechanical separates...	.35	.24	.19	.18	.39	1.39	....	....	....	....
		True aggregates........	4.88	6.04	6.16	4.87	5.60	7.49	....	1.17	....	....
Sod	B	Total separates..........	1.95	3.21	4.25	6.44	8.19	12.25	12.84	....	4.1	81.5
		Mechanical separates...	.55	.43	.34	.31	1.08	1.85	....	....	....	....
		True aggregates........	1.40	2.78	2.91	6.13	7.11	10.40	....	.77	....	....
Cultivation	A	Total separates..........	3.28	3.93	5.16	5.15	5.39	12.77	12.68	....	3.8	84.3
		Mechanical separates...	.47	.32	.35	.39	.62	3.09	....	....	....	....
		True aggregates........	2.81	3.61	4.81	4.76	4.77	9.68	....	.88	....	....
Cultivation	B	Total separates..........	1.26	4.00	4.75	5.91	7.49	13.07	12.70	....	5.5	80.7
		Mechanical separates...	.73	.42	.40	.35	.98	3.08	....	....	....	....
		True aggregates........	.53	3.58	4.35	5.56	6.51	9.99	....	.78	....	....

Mulch

Sod

Cultivation

Mulch

Sod

Cultivation

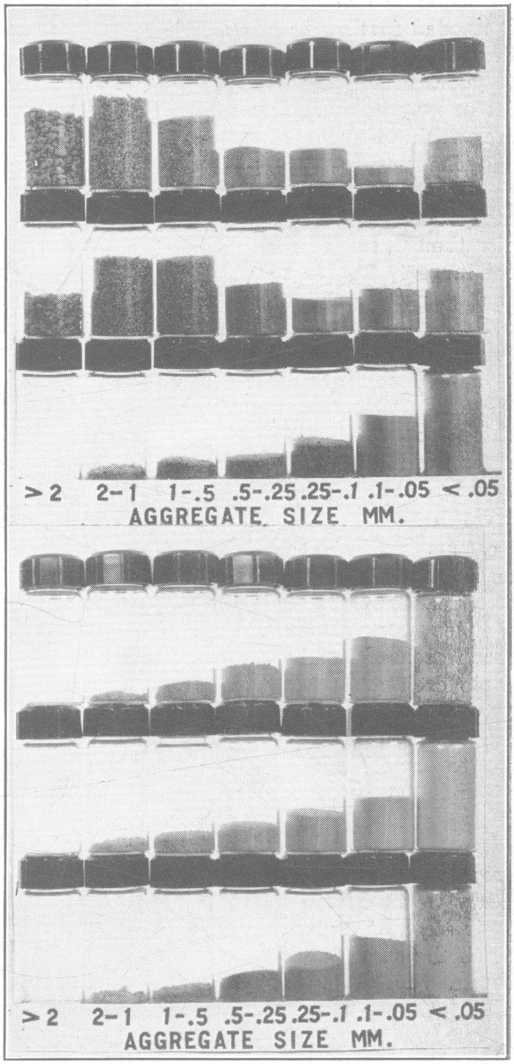

Fig. 3.—Aggregation of Wooster silt loam soil after 44 years under sod and mulch treatments and 16 years under the cultivated treatment. Orchard A

Upper, A horizon
Lower, B horizon

It is not clear why the aggregation in the A horizon under the sod had proceeded farther than under the same treatment in Orchard C. This condition may have been due to the greater length of time the sod had been present, 44 years in Orchard A as compared with 28 years in Orchard C. Another factor may be some difference in the soil in the two orchards, although they are within about 50 yards of each other and on the same soil type.

The pulverization modulus is a convenient single-valued figure which shows the relative degree of aggregation in the different treatments. As used here, it is the sum of the cumulative weights of aggregates of greater diameter than the successive openings in the graded nest of screens, beginning with the largest, divided by 100. This value (table 3) shows that aggregation had been slightly greater in horizon A of the cultivated treatment than in the B horizon under the mulch and sod. The more accurate comparison, however, is between the different treatments in the same horizon. Here the pulverization modulus is much lower for the cultivated treatment.

There was some difference in the mechanical distribution of mineral particles greater than 0.25 mm. and less than 0.05 mm. (table 3), but these differences are minor in comparison with those of distribution of aggregates under the three treatments (table 3).

Peach orchard.—Results obtained by aggregate analysis of the different treatments in the peach orchard indicate what may be expected when treatments have been in effect a much shorter period than in Orchards C and A. The treatments in the peach orchard had been in progress 7 years when the samples were taken for aggregate analysis. The cover crop growth in the peach orchard has been much greater each year than that obtained in the two apple orchards. Organic matter determinations showed no great difference between treatments in the peach orchard up to 1941.

The aggregation results (table 4 and fig. 4) indicate that in order of highest to lowest percentage of the larger aggregates, the treatments were: mulch, chopped corn stover, manure, bluegrass sod, cover crops (Sudan grass and rye), and cultivation with cover crops of soybeans and rye (table 4). The mulch was outstanding in its high degree of aggregation, which was out of proportion to its relative soil organic matter value. The other plots were fairly well arranged according to their soil organic matter content, as well as their state of aggregation. The distribution of the mechanical particles was much the same in all treatments and would account for little of the difference obtained from the aggregate analysis (table 4).

RESULTS WITH SHORT-TIME SOIL TREATMENTS

Small soil plots were prepared in order to determine the effects of certain types of mulch and other treatments over a short period on aggregation of the soil. It was possible by use of these plots to obtain the desired soil conditions without very much soil variation. Although the surface soil used in these tests had been under cultivation for many years, it contained considerable organic matter from additions of manure and cover crops.

TABLE 4.—Aggregation and mechanical analysis of A and B horizons after 7 years under different cultural systems in the peach orchard (Wooster silt loam)

Treatment	Horizon		Size classes in mm. Average oven-dry weight in gm. per 50 gm. of air-dry soil >2	2-1	1-0.5	0.5-0.25	0.25-0.105	0.105-0.05	<0.05	Pulverization modulus	Mineral particles >0.25 Pct.	Mineral particles <0.05 Pct.
Manure	A	Total separates	2.87	4.93	9.77	7.43	7.91	9.29	7.02	...	6.5	80.5
		Mechanical separates	.73	.63	.65	.56	1.08	1.46	...	...	...	...
		True aggregates	2.14	4.30	9.12	6.87	6.83	7.83	...	1.13	...	...
Manure	B	Total separates	3.61	5.28	8.19	5.70	7.88	9.31	9.22	...	10.6	71.9
		Mechanical separates	1.75	1.06	.83	.68	2.09	1.88	...	...	...	...
		True aggregates	1.86	4.22	7.36	5.02	5.79	7.43	...	.96	...	...
Wheat straw	A	Total separates	8.08	6.53	8.52	6.07	6.09	7.78	6.26	...	5.6	79.4
		Mechanical separates	1.02	.65	.55	.39	.68	1.77	...	...	...	...
		True aggregates	7.06	5.88	7.97	5.68	5.41	6.01	...	1.38	...	...
Wheat straw	B	Total separates	3.38	4.75	9.16	7.85	7.40	8.22	8.41	...	8.6	76.7
		Mechanical separates	1.64	.57	.90	.69	1.09	1.91	...	...	...	...
		True aggregates	1.74	4.18	8.26	7.16	6.31	6.31	...	1.05	...	...
Chopped corn stover	A	Total separates	4.25	5.82	8.91	7.75	6.06	8.54	7.09	...	6.5	81.1
		Mechanical separates	.78	.60	.54	.42	.95	1.93	...	...	...	...
		True aggregates	3.47	5.22	8.37	7.33	5.11	6.61	...	1.19	...	...
Chopped corn stover	B	Total separates	1.50	4.50	7.70	6.80	8.16	12.07	8.31	...	6.1	77.9
		Mechanical separates	.58	.42	.49	.35	1.00	2.75	...	...	...	...
		True aggregates	.92	4.08	7.21	6.45	7.16	9.32	...	.98	...	...
Soybeans and rye cover crop	A	Total separates	2.35	4.47	5.87	7.43	6.19	13.39	9.57	...	8.5	78.0
		Mechanical separates	.55	.48	.74	.71	1.07	3.15	...	...	...	...
		True aggregates	1.80	3.99	5.13	6.72	5.12	10.24	...	.92	...	...
Soybeans and rye cover crop	B	Total separates	2.05	2.77	5.37	6.00	4.00	14.97	13.32	...	8.7	74.2
		Mechanical separates	.96	.80	.79	.63	.90	4.43	...	...	...	...
		True aggregates	1.09	1.97	4.58	5.37	3.10	10.54	...	.68	...	...
Sudan grass and rye cover crop	A	Total separates	3.57	4.94	7.42	7.55	7.72	10.76	7.31	...	5.3	82.5
		Mechanical separates	1.03	.56	.61	.47	.74	1.96	...	...	...	...
		True aggregates	2.54	4.38	6.81	7.08	6.98	8.80	...	1.08	...	...
Sudan grass and rye cover crop	B	Total separates	1.97	5.08	8.63	7.40	6.64	11.81	7.71	...	6.1	82.2
		Mechanical separates	1.03	.58	.62	.46	1.23	3.52	...	...	...	...
		True aggregates	.94	4.50	8.01	6.94	5.41	8.29	...	1.00	...	...
Bluegrass sod	A	Total separates	3.80	5.64	7.70	7.10	6.22	11.07	7.48	...	7.1	79.0
		Mechanical separates	.89	.46	.52	.45	1.26	2.51	...	...	...	...
		True aggregates	2.91	5.18	7.18	6.65	4.96	8.56	...	1.10	...	...
Bluegrass sod	B	Total separates	3.05	5.10	8.09	6.93	6.54	10.58	7.91	...	10.9	71.6
		Mechanical separates	1.99	1.02	.77	.66	2.23	2.59	...	...	...	...
		True aggregates	1.06	4.08	7.32	6.27	4.31	7.99	...	.91	...	...

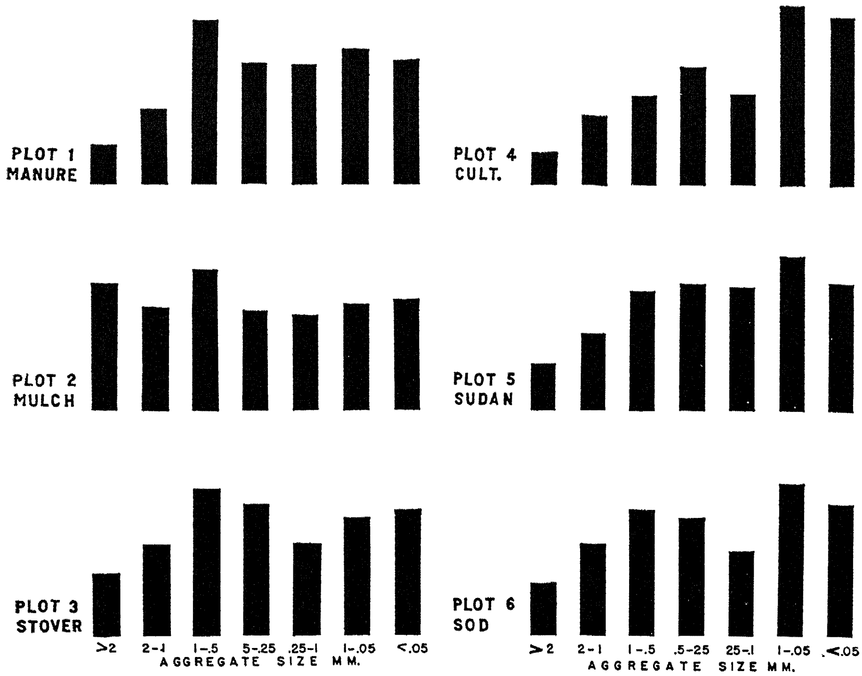

Fig. 4.—Effect of soil treatments in the peach orchard on aggregate analysis of the surface soil (A horizon) of Wooster silt loam. Note high proportion of large aggregates found in plot 2 under mulch treatment.

See text for details of treatments.

The greatest degree of aggregation, as shown by the pulverization modulus (table 5), was brought about by addition of the 2 pounds of sucrose (plot 10). In all plots on which sucrose was used, the aggregation of the soil was relatively high (fig. 5). It can be noted that unleached or new wheat straw was of considerably more value in the formation of aggregates than old or leached material (plot 1). For some reason, ground cork mulch caused slightly more aggregation than either leached wheat straw or rock wool. The lowest degree of aggregation was found in the mixture of surface and subsoil.

A comparison of the data obtained at the three sampling dates, approximately a month apart (tables 5, 6, and 7), shows that aggregation was highest at the first sampling date. The pulverization modulus given in the tables illustrates this condition clearly. However, the same trend as a result of the treatments was found at all the sampling dates. Evidently, when materials necessary for soil aggregation are present, the soil and organic matter particles react very quickly and aggregates are formed. These results seem to indicate that microbiological activity is the principal causative or generative factor in the formation of aggregates in this soil. Although organic matter and clay particles are necessary for soil aggregation and are the principal materials aggregated, their mere presence does not ensure a high state of aggregation.

TABLE 5.—Aggregation and mechanical analysis of Wooster silt loam under different treatments at three successive dates after treatment April 27, 1942

Test of June 8, 1942

Plot	Treatment		Size classes in mm.									
			Average oven-dry weight in gm. per 50 gm. of air-dry soil							Pulverization modulus	Mineral particles	
			>2	2-1	1-0.5	0.5-0.25	0.25-0.105	0.105-0.05	<0.05		>0.25	<0.05
											Pct.	*Pct.*
1	Old wheat straw mulch	Total separates	1.69	5.13	10.60	10.27	8.84	7.15	5.15	...	3.4	86.0
		Mechanical separates	.40	.47	.68	.71	.85	1.55	...	...	...	...
		True aggregates	1.29	4.66	9.92	9.56	7.99	5.60	...	1.21	...	...
2	New wheat straw mulch, plus 1 lb. of sucrose	Total separates	2.69	8.46	13.25	8.56	6.42	4.37	4.05	...	2.9	86.3
		Mechanical separates	.30	.33	.49	.52	.55	.85	...	...	...	...
		True aggregates	2.39	8.13	12.76	8.04	5.87	3.52	...	1.45	...	...
3	New wheat straw mulch	Total separates	2.79	6.52	12.54	9.32	5.85	6.35	5.55	...	3.0	86.5
		Mechanical separates	.42	.34	.48	.46	.40	1.24	...	...	...	...
		True aggregates	2.37	6.18	12.06	8.86	5.45	5.11	...	1.36	...	...
4	New alfalfa mulch	Total separates	3.40	6.62	12.09	8.68	7.19	5.77	4.77	...	3.3	86.1
		Mechanical separates	.25	.35	.50	.34	.62	1.14	...	...	...	...
		True aggregates	3.15	6.27	11.59	8.34	6.57	4.63	...	1.39	...	...
5	Ground cork mulch	Total separates	2.17	4.56	12.83	9.64	8.15	5.75	5.59	...	2.9	86.6
		Mechanical separates	.50	.32	.36	.37	.80	1.25	...	...	...	...
		True aggregates	1.67	4.24	12.47	9.27	7.35	4.50	...	1.28	...	...
6	Ground cork mulch, plus 1 lb. of sucrose	Total separates	3.72	6.46	12.34	9.81	7.25	5.84	4.20	...	3.3	86.2
		Mechanical separates	.34	.29	.35	.40	.61	1.48	...	...	...	...
		True aggregates	3.38	6.17	11.99	9.41	6.64	4.36	...	1.45	...	...

TABLE 5.—Aggregation and mechanical analysis of Wooster silt loam under different treatments at three successive dates after treatment April 27, 1942—continued

Test of June 8, 1942

Plot	Treatment		Size classes in mm. Average oven-dry weight in gm. per 50 gm. of air-dry soil							Pulverization modulus	Mineral particles	
			>2	2-1	1-0.5	0.5-0.25	0.25-0.105	0.105-0.05	<0.05		>0.25	<0.05
											Pct.	Pct.
7	Topsoil, plus 7 lb. of hydrated lime	Total separates	4.67	4.72	12.39	9.26	6.68	6.49	4.88	....	3.1	85.5
		Mechanical separates	.45	.26	.32	.35	.71	1.50	....	....	....	....
		True aggregates	4.22	4.46	12.07	8.91	5.97	4.99	....	1.40	....	....
8	Mixture of A and B horizons, 50 per cent each	Total separates	1.95	4.05	9.53	8.50	8.74	8.38	7.63	....	1.9	87.0
		Mechanical separates	.38	.15	.24	.35	1.24	2.66	....	....	....	....
		True aggregates	1.57	3.90	9.29	8.15	7.50	5.72	....	1.11	....	....
9	Topsoil, plus 1 lb. of sucrose on surface	Total separates	6.38	7.71	13.51	8.45	5.65	4.16	3.12	....	3.4	86.0
		Mechanical separates	.65	.30	.34	.25	.47	.95	....	....	....	....
		True aggregates	5.73	7.41	13.17	8.20	5.18	3.21	....	1.62	....	....
10	Topsoil, plus 2 lb. of sucrose	Total separates	10.87	10.58	9.82	6.39	4.41	4.42	2.64	....	3.1	86.3
		Mechanical separates	.45	.32	.32	.25	.44	1.04	....	....	....	....
		True aggregates	10.42	10.26	9.50	6.14	3.97	3.38	....	1.82	....	....
11	Rock wool mulch	Total separates	1.29	3.42	9.19	12.87	8.33	8.23	6.09	....	3.2	86.4
		Mechanical separates	.36	.33	.52	.52	.93	1.79	....	....	....	....
		True aggregates	.93	3.09	8.67	12.35	7.40	6.44	....	1.14	....	....
12	Rock wool plus 1 lb. of sucrose	Total separates	2.02	3.59	11.33	13.34	8.56	5.52	4.57	....	3.1	86.1
		Mechanical separates	.69	.31	.39	.32	.69	1.15	....	....	....	....
		True aggregates	1.33	3.28	10.94	13.02	7.87	4.37	....	1.21	....	....

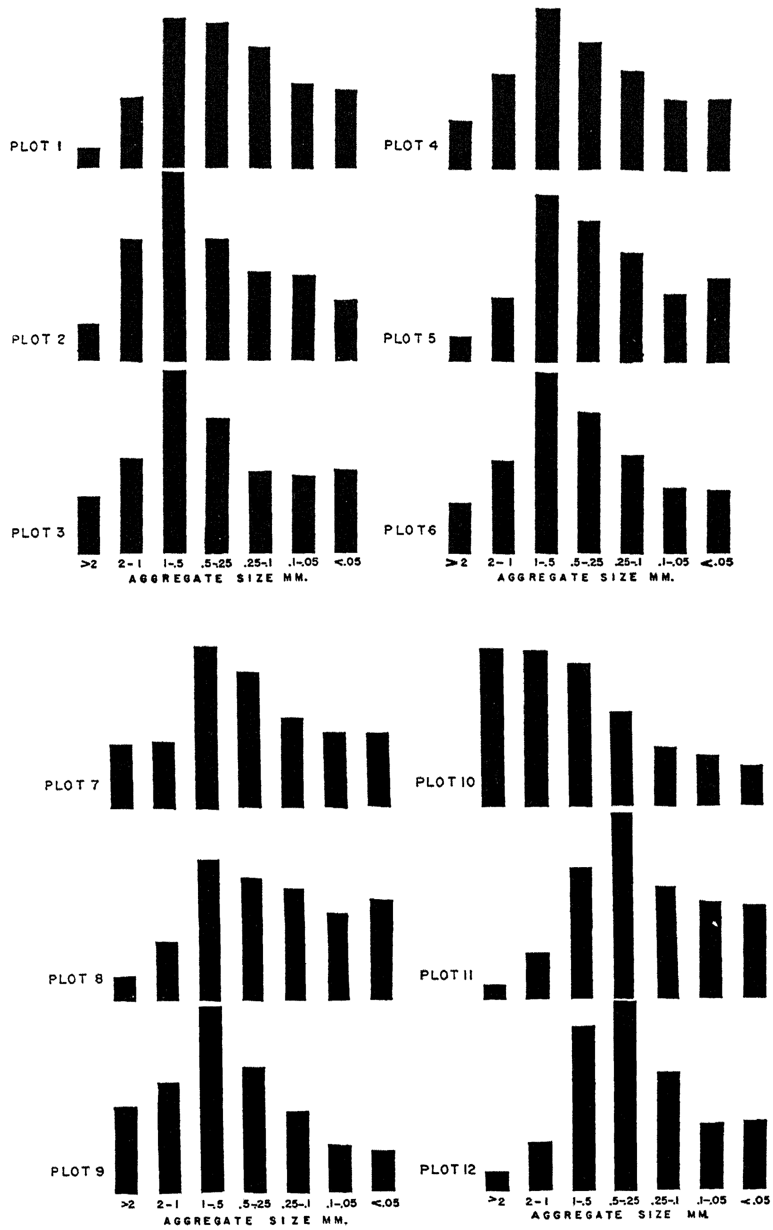

Fig. 5.—The effect of short-time soil treatments on aggregation of Wooster silt loam soil. These graphs show relative aggregate analysis on June 8, 6 weeks after treatment.

See text for outline of plot treatments shown.

TABLE 6.—Aggregation and mechanical analysis of Wooster silt loam under different treatments at three successive dates after treatment April 27, 1942

Test of July 8, 1942

Plot	Treatment		Size classes in mm.							
			Average oven-dry weight in gm. per 50 gm. of air-dry soil							Pulverization modulus
			>2	2-1	1-0.5	0.5-0.25	0.25-0.105	0.105-0.05	<0.05	
1	Old wheat straw mulch	Total separates	1.95	4.30	8.99	7.87	9.22	6.87	9.05	
		Mechanical separates	.47	.34	.50	.44	.96	1.20		
		True aggregates	1.48	3.96	8.49	7.43	8.26	5.67		1.07
2	New wheat straw, plus 1 lb. of sucrose	Total separates	2.15	3.60	8.45	7.80	8.28	8.22	8.66	
		Mechanical separates	.25	.50	.55	.43	1.89	2.26		
		True aggregates	1.90	3.10	8.90	7.37	6.39	5.96		1.03
3	New wheat straw mulch	Total separates	3.87	6.31	11.14	7.64	6.88	6.08	6.97	
		Mechanical separates	.32	.31	.42	.52	1.11	1.53		
		True aggregates	3.55	6.00	10.72	7.12	5.77	4.55		1.32
4	New alfalfa mulch	Total separates	2.05	5.49	13.14	7.36	9.29	4.56	6.13	
		Mechanical separates	.21	.38	.38	.34	1.19	1.11		
		True aggregates	1.84	5.11	12.76	7.02	8.10	3.45		1.28
5	Ground cork mulch	Total separates	1.55	3.43	9.25	11.21	8.97	8.06	6.48	
		Mechanical separates	.43	.26	.37	.38	.65	1.85		
		True aggregates	1.12	3.17	8.88	10.83	8.32	6.21		1.13
6	Ground cork mulch, plus 1 lb. of sucrose	Total separates	1.67	8.16	9.40	7.40	7.05	7.79	7.05	
		Mechanical separates	.39	.41	.34	.29	1.07	2.15		
		True aggregates	1.28	7.75	9.06	7.11	5.98	5.64		1.22
7	Topsoil plus 7 lb. of hydrated lime	Total separates	3.70	5.25	10.95	10.33	6.20	6.12	6.36	
		Mechanical separates	.34	.51	.81	.72	1.14	1.00		
		True aggregates	3.66	4.74	10.14	9.61	5.06	5.12		1.30
8	Mixture of A and B horizons, 50 per cent each	Total separates	.97	2.26	6.92	6.82	8.25	9.87	13.21	
		Mechanical separates	.23	.23	.48	.44	.65	1.00		
		True aggregates	.74	2.03	6.44	6.38	7.60	8.87		.84
9	Topsoil, plus 1 lb. of sucrose on surface	Total separates	3.24	5.95	12.12	8.92	5.75	6.22	6.84	
		Mechanical separates	.42	.40	.64	.48	.59	.73		
		True aggregates	2.82	5.55	11.48	8.44	5.16	5.49		1.32
10	Topsoil, plus 2 lb. of sucrose	Total separates	7.19	9.22	11.79	6.23	4.24	5.28	4.72	
		Mechanical separates	.42	.42	.48	.25	.34	.52		
		True aggregates	6.77	8.80	11.31	5.98	3.90	4.76		1.60
11	Rock wool mulch	Total separates	1.83	2.71	9.44	10.76	8.02	5.61	9.87	
		Mechanical separates	.35	.41	.74	.50	1.14	.58		
		True aggregates	1.48	2.30	8.70	10.26	6.88	5.03		1.05
12	Rock wool, plus 1 lb. of sucrose	Total separates	2.86	5.01	9.31	8.63	10.05	5.44	7.20	
		Mechanical separates	.40	.45	.64	.58	.98	.65		
		True aggregates	2.46	4.56	8.67	8.05	9.07	4.79		1.19

TABLE 7.—Aggregation and mechanical analysis of Wooster silt loam under different treatments at three successive dates after treatment April 27, 1942

Test of August 10, 1942

Plot	Treatment		Size classes in mm: Average oven-dry weight in gm. per 50 gm. of air-dry soil							Pulverization modulus
			>2	2-1	1-0.5	0.5-0.25	0.25-0.105	0.105-0.05	<0.05	
1	Old wheat straw mulch	Total separates	1.16	2.30	6.71	8.32	10.20	10.25	8.61	...
		Mechanical separates	.32	.28	.38	.78	1.89	2.87	...	...
		True aggregates	.84	2.02	6.33	7.54	8.31	7.38	...	0.87
2	New wheat straw, plus 1 lb. of sucrose	Total separates	1.54	3.20	7.95	7.64	8.72	9.55	8.93	...
		Mechanical separates	.39	.25	.40	.55	1.17	2.64	...	...
		True aggregates	1.15	2.95	7.55	7.09	7.55	6.91	...	.95
3	New wheat straw mulch	Total separates	2.96	6.73	10.86	8.18	5.72	7.79	7.33	...
		Mechanical separates	.45	.32	.37	.38	.60	1.89	...	...
		True aggregates	2.51	6.41	10.49	7.80	5.12	5.90	...	1.29
4	New alfalfa mulch	Total separates	1.63	3.41	8.53	8.33	8.66	8.34	8.69	...
		Mechanical separates	.22	.32	.58	.49	1.17	2.45	...	...
		True aggregates	1.41	3.09	7.95	7.84	7.49	5.89	...	1.00
5	Ground cork mulch	Total separates	1.42	4.59	8.71	10.99	8.55	7.73	7.36	...
		Mechanical separates	.38	.29	.32	.35	.74	1.70	...	...
		True aggregates	1.04	4.30	8.39	10.64	7.81	6.03	...	1.15
6	Ground cork mulch, plus 1 lb. of sucrose	Total separates	1.31	4.69	7.82	8.74	9.99	7.55	7.69	...
		Mechanical separates	.25	.34	.35	.38	1.31	1.73	...	...
		True aggregates	1.06	4.35	7.47	8.36	8.68	6.22	...	1.07
7	Topsoil, plus 7 lb. of hydrated lime	Total separates	4.41	4.73	9.61	7.70	8.14	8.67	5.49	...
		Mechanical separates	.36	.28	.42	.54	1.61	2.33	...	...
		True aggregates	4.05	4.45	9.19	7.16	6.53	6.34	...	1.24
8	Mixture of A and B horizons, 50 per cent each	Total separates	1.64	2.37	6.97	6.88	8.35	11 31	11.09	...
		Mechanical separates	.35	.18	.27	2.19	3.58	3.58	...	...
		True aggregates	1.29	2.19	6.70	6.61	6.16	7.73	...	.85
9	Topsoil, plus 1 lb. of sucrose on surface	Total separates	6.25	9.90	9.56	5.62	6.40	6.49	4.77	...
		Mechanical separates	.27	.41	.29	.25	.86	1.38	...	...
		True aggregates	5.98	9.49	9.27	5.37	5.54	5.11	...	1.53
10	Topsoil, plus 2 lb. of sucrose	Total separates	9.21	8.35	9.15	5.48	4.55	5.25	6.37	...
		Mechanical separates	.52	.29	.29	.21	.48	1.48	...	...
		True aggregates	8.69	8.06	8.86	5.27	4.07	3.77	...	1.91
11	Rock wool mulch	Total separates	.98	2.51	8.18	9.09	9.68	8.59	9.21	...
		Mechanical separates	.45	.39	.43	.51	1.44	1.31	...	...
		True aggregates	.53	2.12	7.75	8.58	9.24	7.28	...	.96
12	Rock wool, plus 1 lb. of sucrose	Total separates	1.31	2.81	7.78	9.59	9.86	8.59	8.19	...
		Mechanical separates	.32	.39	.40	.46	1.18	1.93	...	...
		True aggregates	.99	2.42	7.38	9.13	8.68	6.66	...	.99

The distribution of the mechanical particles greater than 0.25 mm. and those less than 0.05 mm. in diameter showed that the soils were uniform when only the surface soil was considered. The plot in which a mixture of surface and subsoil was used showed a lower percentage of mineral particles greater than 0.25 mm. and a higher percentage of those less than 0.05 mm. than the other plots (table 5).

RESULTS WITH VEGETABLE SOILS AT MARIETTA

The results from soils obtained at the Marietta Truck Farm in southeastern Ohio represent two specific soil types, the Chenango loam and the Chenango fine sandy loam. These Chenango soils are relatively high in sand and low in clay particles. They are considered good garden soils, however, and have been productive when fertilized correctly (5). The organic matter of these soils has been found to be low in all the plots (8), but it was significantly higher in plots receiving applications of manure each year.

The Marietta soils were found to be slightly less aggregated in comparison with those of the Wooster series already described. Furthermore, there was not so much difference between different treatments (fig. 6).

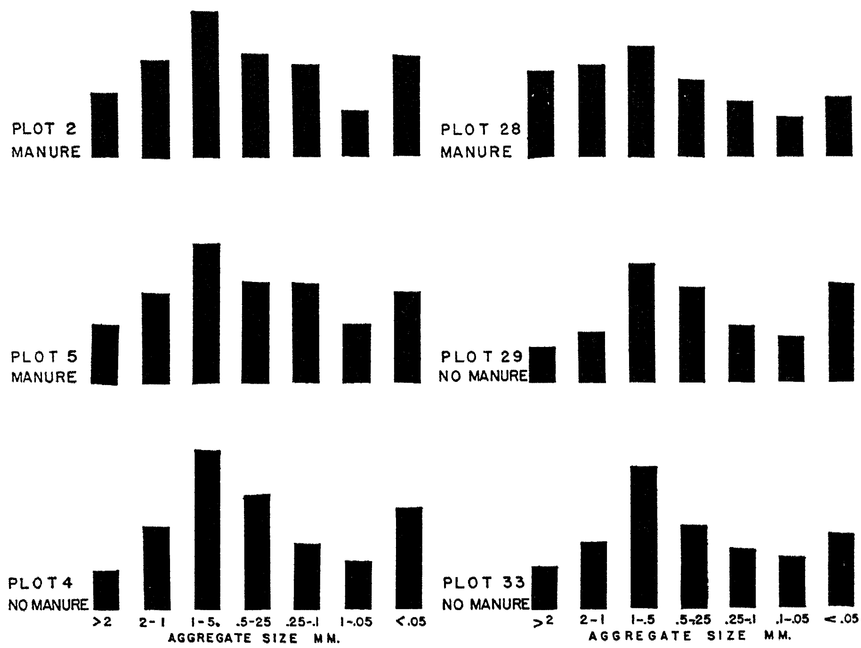

Fig. 6.—Effect of application of manure over a 28-year period on aggregate analysis of surface soil of Chenango loam (left) and Chenango fine sandy loam (right).

See table 1 for details of treatments.

Chenango loam.—Plots 2, 3, and 5 of the Chenango loam soil had received applications of manure throughout the 28-year period. There was some tendency for the aggregates to be larger than in plots 4 and 22 (no manure), but this condition was not always present, and the differences were not great (table 8). Plot 22, which had received no manure, had a higher degree of aggregation, as shown by the pulverization modulus (table 8), than plot 3, which had been manured. The difference was not great, however, and was probably not significant.

The B horizon in all the soil treatments in the Chenango loam was very poorly aggregated. Probably the differences between treatments in this horizon were due largely to differences in mechanical composition of the soil.

Chenango fine sandy loam.—Plot 28, which had received an annual application of 16 tons of manure for 28 years, was in a higher state of aggregation than either plot 29 or plot 33, neither of which had received manure. Nevertheless, the percentage of aggregates larger than 0.25 mm. is not high in comparison with many soils. It is probably not possible by any ordinary cultural treatment to cause this type of soil to become highly aggregated. The untreated plots in this Chenango fine sandy loam showed a very low percentage of aggregation both in the A and in the B horizons (table 9).

The mechanical analysis of these plots showed that this soil type contained a high percentage of sand and a relatively low proportion of clay. The different plots were fairly uniform in this respect (table 9).

TABLE 8.—Aggregation and mechanical analysis of Chenango loam soil after 28 years under different treatments

Plot	Horizon		Size classes in mm.									
			Average oven-dry weight in gm. per 50 gm. of air-dry soil							Pulverization modulus	Mineral particles	
			>2	2-1	1-0.5	0.5-0.25	0.25-0.105	0.105-0.05	<0.05		>0.25	<0.05
											Pct.	*Pct.*
2	A	Total separates	5.48	7.12	11.63	7.63	6.85	3.61	5.66		19.4	71.2
		Mechanical separates	1.94	1.63	3.45	1.78	1.59	1.06				
		True aggregates	3.54	5.49	8.18	5.85	5.26	2.55		1.12		
2	B	Total separates	1.70	3.67	7.85	7.98	10.24	5.85	11.47		22.9	67.4
		Mechanical separates	1.17	1.11	3.21	3.88	4.44	2.60				
		True aggregates	.53	2.56	4.64	4.10	5.80	3.25		.62		
3	A	Total separates	4.51	5.64	10.63	8.11	8.43	4.50	5.98		19.4	71.5
		Mechanical separates	1.94	1.50	3.61	2.03	2.00	1.36				
		True aggregates	2.57	4.14	7.02	6.08	6.43	3.14		.98		
3	B	Total separates	1.71	3.77	7.51	5.36	7.95	8.06	13.77		19.7	70.3
		Mechanical separates	1.33	1.23	3.49	2.08	2.29	2.88				
		True aggregates	.38	2.54	4.02	3.28	5.66	5.18		.57		
4	A	Total separates	4.01	6.27	12.57	8.24	6.27	4.76	5.76		15.0	82.2
		Mechanical separates	2.00	1.47	3.49	1.71	1.57	2.01				
		True aggregates	2.01	4.80	9.08	6.53	4.70	2.75		.96		
4	B	Total separates	1.59	2.25	8.77	7.28	8.81	6.42	13.07		19.3	70.3
		Mechanical separates	1.33	1.52	4.01	2.21	2.43	2.59				
		True aggregates	.26	.73	4.76	5.07	6.38	3.83		.56		
5	A	Total separates	4.67	6.40	11.14	7.97	7.87	4.64	5.08		18.4	67.0
		Mechanical separates	1.33	1.30	3.24	2.16	2.29	1.42				
		True aggregates	3.34	5.10	7.90	5.81	5.58	3.22		1.09		
5	B	Total separates	1.81	3.11	7.39	4.00	8.38	8.16	14.34		17.6	70.9
		Mechanical separates	1.30	1.05	3.44	2.13	5.25	2.93				
		True aggregates	.51	2.06	3.95	1.87	3.13	5.23		.46		
22	A	Total separates	4.41	7.31	10.55	8.50	7.59	4.40	5.64		22.7	61.1
		Mechanical separates	1.41	1.78	3.96	2.90	2.60	1.24				
		True aggregates	3.00	5.53	6.59	5.60	4.99	3.16		1.01		
22	B	Total separates	2.23	4.95	7.54	7.24	7.23	4.56	13.90		26.2	62.6
		Mechanical separates	1.92	2.28	4.96	3.16	2.88	1.72				
		True aggregates	.31	2.67	2.58	4.08	4.35	2.84		.49		

TABLE 9.—Aggregation and mechanical analysis of Chenango fine sandy loam soil after 28 years under different treatments

Plot	Horizon		Size classes in mm.									
			Average oven-dry weight in gm. per 50 gm. of air-dry soil							Pulverization modulus	Mineral particles	
			>2	2-1	1-0.5	0.5-0.25	0.25-0.105	0.105-0.05	<0.05		>0.25 *Pct.*	<0.05 *Pct.*
28	A	Total separates	7.47	6.54	9.87	9.36	7.80	4.47	3.38	...	23.3	46.8
		Mechanical separates	2.69	1.31	3.62	4.94	4.64	2.21	...	...	...	...
		True aggregates	4.78	5.23	6.25	4.42	3.16	2.26	...	1.01	...	...
28	B	Total separates	2.08	7.70	10.11	8.78	8.21	4.46	7.91	...	21.0	56.6
		Mechanical separates	1.50	3.23	2.10	4.47	4.86	2.46	...	...	...	...
		True aggregates	.58	4.47	8.01	4.31	3.35	2.00	...	.80	...	...
29	A	Total separates	2.77	3.50	10.54	11.61	9.36	5.20	5.54	...	25.5	44.7
		Mechanical separates	.80	.88	3.95	6.19	6.15	2.68	...	...	...	...
		True aggregates	1.97	2.62	6.59	5.42	3.21	2.52	...	.76	...	...
29	B	Total separates	1.50	1.55	2.51	9.91	14.64	3.54	15.22	...	24.1	54.8
		Mechanical separates	1.20	.83	1.32	6.32	9.16	2.17	...	...	...	...
		True aggregates	.30	.72	1.19	3.59	5.48	1.37	...	.33	...	...
33	A	Total separates	4.33	7.02	10.60	9.50	8.04	5.18	4.17	...	22.0	48.0
		Mechanical separates	1.90	3.16	2.53	4.87	4.76	2.30	...	...	...	...
		True aggregates	2.34	3.86	8.07	4.63	3.28	2.88	...	.89	...	...
33	B	Total separates	1.70	3.74	7.14	7.73	10.13	5.92	12.06	...	24.9	53.4
		Mechanical separates	1.38	2.43	1.51	3.72	6.02	3.15	...	...	...	...
		True aggregates	.32	1.31	5.63	4.01	4.11	2.77	...	.54	...	...

CONCLUSIONS

The results of this study of soil aggregation indicate that Wooster silt loam soil reaches a relatively high state of aggregation under straw mulch such as that often applied around fruit trees. This condition is reached quickly if the mulch is of unleached wheat straw or alfalfa. Bluegrass sod treatment over a long period is of value in increasing and maintaining a high percentage of the aggregates of the larger sizes but is not as effective as mulch. Cultivation, even with such cover crops as can be produced in a mature apple orchard, is very destructive of soil aggregate structure. From the results in the peach orchard, it seems that if large amounts of cover crops can be produced, as they often can be in young orchards, the physical structure of the Wooster soil can be maintained fairly well. The results here also indicate, however, that mulch has a striking value in the formation of aggregates which is out of proportion to differences in organic matter present. The value of mulch and sod in aggregate formation was noted in the subsoil, or B horizon, but the results were not so striking as in the surface soil. Treatments which bring about favorable responses to the physical nature of the deeper soil layers are of special value in orchard soils where the plants root deeply and are perennially in this deeper environment.

Retzer and Russell (15) have pointed out the value of sucrose in increasing the formation of water-stable aggregates in Iowa soils. Evidently this is one of the limiting factors in the Wooster silt loam, for when sucrose was added, there was a rapid increase in aggregation. Lack of any increase in aggregates under mulches of inert materials, such as ground cork and rock wool, indicates that aggregate formation is not increased as a result of the physical influence of the mulch. It seems that without question, some water-soluble substance within the mulch, such as the sugars, plays an important role in the physical nature of the soil structure.

The results with the relatively sandy soils of Marietta show that the application of large amounts of manure over a period of 28 years has not brought about a very high degree of aggregation. It has been increased somewhat over the untreated plots, however. From these results, it seems that there is a definite limit to the improvement that can be made in the physical structure of these soils by the use of even large amounts of manure over many years.

SUMMARY

An analysis was made of the water-stable soil aggregates in the A and B horizons of Wooster silt loam soil which had been under sod, mulch, and cultivation treatments for long periods of time. The treatments in Orchard C had been in progress for 28 years, and the sod and mulch treatments in Orchard A had been continuous for the previous 44 years. The aggregate analysis was made by the Yoder (wet screen) method on air-dry soil. Seven size classes of aggregates were made, varying from a class of those over 2 millimeters in diameter to a class composed of those below 0.05 millimeter.

The amounts of aggregates of various sizes obtained by this method were strikingly different under the sod, mulch, and cultivation treatments. The mulch showed the greatest amount of aggregates among the larger sizes; sod resulted in almost as much aggregation; the cultivated soil contained only small aggregates. Even in the A horizon, there were few soil aggregates over 1.0 mm. in diameter under the cultivation, whereas approximately 28 per cent of the dry weight of the soil under mulch and 23 per cent under sod in Orchard A were composed of aggregates over 1.0 mm. in diameter. The same general trend of differences was indicated in Orchard C. The B horizons in both orchards showed the same trends in results, but the differences between treatments were not nearly so striking.

Results of aggregate analysis of several soil treatments which had been in progress 7 years showed that the state of aggregation was in fairly close relationship to the percentage of soil organic matter, except for the high aggregate formation under wheat straw mulch.

Where sucrose, unleached wheat straw, or unleached alfalfa was placed on Wooster silt loam surface soil, there was a sharp increase in aggregate formation.

Soil aggregation is very limited, even under heavy manure treatments in terrace soils such as the Chenango loam and fine sandy loam. It was poss'ble to increase the state of aggregation slightly, however, by annual applications of manure.

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